Appendix C

Drainwater Reuse

Tables

C1 DRAINAGE REUSE AREA ESTIMATES

The estimates for the sizing of the drainwater reuse areas have gone through several iterations with comments and input from the members of the Drainage Work Group. Some of the estimates still include assumptions from the 2002 Plan Formulation Report work that have not been studied in more detail. These assumptions are noted where applicable.

The return flow from the on-farm drains is the starting point for estimating the acreage needed for reuse. The estimate of the on-farm drainage return flow consisted of making some estimation of the area involved (the drainage service area that would have on-farm drains installed); estimating a representative crop mix for the area; and calculating a cropwater budget that includes some details concerning the types of crops expected to be grown, planting dates, harvest dates, rate of cropwater use, soil moisture depletions, irrigation schedule, and resulting deep percolation amounts that end up being drainwater. Also, a timing component indicates when the drainwater is to flow from the on-farm drains to the drainwater reuse areas.

C2 DRAINAGE SERVICE AREA

The drainage-impaired area has been identified by others and has been defined as the area requiring on-farm drains for the control of the soil salinity and water table depth. These controls are necessary to provide support of agricultural crop production. The assumption in the 2002 Plan Formulation Report was that not all of the lands within the drainage-impaired area would have on-farm drains installed. The assumption has been that two-thirds of the drainage-impaired area would actually install the subsurface drainage systems. Also, some lands within the drainage-impaired area have been retired from agricultural production for various reasons. These retired acres are assumed to not require subsurface drains in the future.

C3 DRAINAGE RETURN FLOW FROM THE COMMERCIAL IRRIGATED AREA

The quantity of drainwater expected to flow from the on-farm drains is a function of many variables. To arrive at an estimate of the quantity and the timing of the return flows, several assumptions are required. The types of crops expected to be grown within the drainage-impaired area have a significant influence on the production of drainwater. These crops have a specific irrigation requirement and, therefore, a specific drainage production. A crop mixture grown in the past has been used as an indication of the crops expected to be grown in the future. Too many variables occur in the decisions to plant a certain crop than can be estimated; therefore, a reasonable assumption is to use the historical crop patterns.

The main crops used to estimate drainage from on-farm drains are alfalfa, cotton, sugarbeets, a selection of crops to comprise a category for vegetables, which includes tomato, onions, garlic, broccoli, melons, lettuce, and some orchard and small grain crops. The drainage from each of these crops is different due to the amount and timing of irrigation applications. The crop with the greatest drainage requirement is used to determine the on-farm drain spacing; however, the quantity and timing of the drainage flows is a combination of all crops grown in the area.

An irrigation schedule has been created for each of the sample crop types. The schedule takes into consideration the soil moisture reservoir, planting and harvesting times, daily cropwater use, irrigation events, and irrigation efficiency. The daily cropwater use is based on climatic data recorded at the California Irrigation Management Information System CIMIS 105 site near Tranquility and is for an average climatic year.

C4 ON-FARM DRAINS

The drainage flows from all crop areas are aggregated to create the flow from the on-farm drains. This drainflow would be used as the irrigation water for the salt-tolerant plants at the reuse sites. This flow is only needed at times when the reuse area crops are actively growing. To accomplish this, flow regulation is necessary for the on-farm drains and some water table storage is also required. Calculations of the amount of storage required by the on-farm drains shows that about 1.3 vertical feet of water table depth are needed. In other words, if on-farm drains are normally installed at a depth of 8 feet, then a depth of 9.3 feet is needed to provide the proper amount of seasonal storage.

C5 DRAINWATER REDUCTION

The drainflow generated from the on-farm drains would be reduced by applying drainwater reduction (source control) measures to help minimize the quantity of drainwater flowing to the reuse areas. Two measures, shallow water table management and recycling, have been implemented for this analysis. The implementation of shallow water table management requires on-farm monitoring of the water table and control structures in the drainage system. The objective of this control measure is to provide an opportunity for the crops to use water from the water table before it is discharged from the fields. This measure requires some investment in water level control devices, monitoring wells, and management time. It also has some limitations due to the salinity of the water table and the growth stage of the crops. It has been assumed that only a portion of the acreage would be managed for this source control and that the overall effect would be a net reduction of drainwater of 4,921 acre-feet (AF)/year in Westlands Water District (Westlands) and 810 AF/year in the Northerly Area. (Source Control Memorandum [URS 2002]).

Drainwater recycling as a drainwater reduction/source control method has been assumed to be implemented. Recycling involves collecting water from the on-farm drains and then pumping a small portion back into the supply water to be reused again. The amount of water that can be recycled is limited due to the salinity and boron of the drainwater. The assumption in the Source Control Memorandum is that recycling and blending can occur up to a mixture of approximately 600 parts per million of total dissolved solids. To stay below this limit, recycling is assumed to take place for about 12,302 AF of drainwater per year for Westlands and a total of 4,700 AF/year for the Northerly Area. The drainwater that is recycled does not have to be delivered to the reuse areas.

C6 REUSE SITE LOCATIONS

Reuse site locations have been investigated in the field for soil suitability and drainage characteristics. Site locations are somewhat scattered throughout Westlands to minimize the amount of pumping and to minimize the pipeline sizes needed to transfer drainwater. Additionally, site locations are preferred on land that has been retired rather than active commercial agricultural lands. Not all of the reuse areas could be located on retired lands. In some cases it was more economical to purchase good commercial irrigated land and establish reuse, rather than have large pipelines and larger pumping plants to move the drainwater to areas that are retired acreages.

Where possible, a reuse area has been designated around each evaporation pond. The purpose of this location requirement is to provide a buffer between the evaporation pond and the adjacent commercial irrigated area. In addition, the reuse areas would have subsurface drains that are deeper than most on-farm drains and would**,** therefore, provide some water table interception near each pond.

C7 REUSE SITE SIZING

To maintain the purpose of the reuse sites, which is to consume drainwater by plants so as to reduce the volume of water that has to be pumped, treated, or stored, each reuse site would have to be planted to salt-tolerant crops. These crops would be a mixture of mostly perennial salt-tolerant grasses. The actual cropwater use of these grasses would be dependent upon many variables, one of which is the type of soil within the reuse area. Land suitability for reuse has been evaluated, and the production potential of the soil types has been rated. The land area that is a Grade 1 would have the best cropping potential and, therefore, the plants would grow at the best rate and use the most water. Similarly, Grades 2 and 3 are expected to produce slightly less and, therefore, have a slightly lower cropwater requirement. Table C-1 provides a summary of the reuse areas and the production potential Grades 1 thru 3 and 6, which are not recommended for reuse.

Table C-1
Reuse Area Land Suitability Study

Reuse Area	Grade 1 (acres)	Grade 2 (acres)	Grade 3 (acres)	Grade 4 (acres)	Usable (acres)	Grade 6 (acres)	Total
B		1,425	8,670	745	10,840	390	11,230
C			2,740	650	3,390	400	3,790
D	310	2,030	200		2,540	20	2,560
E		1,280			1,280		1,280
F		800			800		800
G		685	3,325	110	4,120		4,120
H		1,590	810		2,400		2,400
I,J,K			3,040		3,040	160	3,200
L			1,090	295	1,385	355	1,740
M		1,050	1,415	425	2,890		2,890
N		855	345		1,200		1,200
O			1,760	120	1,880	140	2,020
Totals:	**310**	**9,715**	**23,395**	**2,345**	**35,765**	**1,465**	**37,230**

Cropwater requirement is expected to be met during the winter months by rainfall and, therefore, no irrigation requirement is estimated from mid-November until mid-March. The crop production potential, based on the land suitability study for reuse areas, is shown in Table C-1.

Sizing of the reuse areas is based upon the expected crop evapotranspiration, which is shown as dependent upon production potential grade and has been estimated in Table C-2.

Table C-2
Crop Evapotranspiration by Land Grade

	Crop Evapotranspiration (AF/yr)	Effective Rainfall (AF/yr)	Crop Irrigation Requirement (CIR) (AF/yr)	Irrigation Deep Percolation (percent)	Farm Delivery Requirement (AF/yr)
Land Grades 1 and 2	3.87	0.53	3.34	27	4.58
Grade 3	3.4	0.49	2.91	27	3.99
Grade 4	3.3	0.46	2.84	27	3.89

Site selection of each reuse area allows us to pick the better land areas to be used, resulting in using Grade 1, 2, and 3 areas only.

C8 REUSE AREA DRAINAGE

The drainage system is an important part of the reuse areas since without drainage the soils would soon become saline and the water table would remain near the ground surface. An initial soils investigation has been completed to gather site-specific data on the drainage properties of the potential reuse areas and make sure that drainage systems could be designed and constructed. Field investigation of the proposed reuse sites included soil identification and sampling to depths of 30 feet with hydraulic conductivity tests of soil layers below the water table. A total of 107 deep soils logs were completed with about 185 hydraulic conductivity tests conducted. Along with soil hydraulic conductivity, the depth to any barrier layers was noted. Barrier layers prevent vertical infiltration of groundwater, thereby causing perching water tables that can rise into the crop root zone. Barrier layers also play a role in the design spacing and depth of the subsurface drains. See Table C-3 below.

Table C-3
Geomean of Hydraulic Conductivity Tests and Barrier for Selected Subset of the Reuse Areas

Reuse Area	Subsurface Drain Spacing (feet)	Hydraulic Conductivity (feet/day)	Barrier Depth (feet)
B	200	1.49	12.6
C	270	2.32	13.8
D	225	1.27	15.9
E	485	7.11	13.9
F	325	2.22	18.2
G	310	2.11	17.4
H	280	2.72	13.1
I	245	2.07	13
J	330	1.86	21.4
K	325	3.57	13.1
L	195	0.57	30
M	655	6.05	23.9
N	440	3.62	19.5
O	345	2.89	16.2
Z	311	4.86	10.8

The individual reuse areas have been investigated, and the general subsoil properties of each represent the estimated drain spacing. The drain depth and spacing also determine the drainage cost for each reuse site.

The drainage system for the reuse area would consist of perforated drain tubing with a gravel envelope. The drains would be placed deeper than conventional drainage systems to provide for groundwater storage, a deeper average depth to water to minimize upflux of water and salts, and a steady rate of discharge for water treatment plant operations. The discharge would be by pumping through a pipeline to the reverse osmosis treatment plants. Some additional flow control devices would be needed in the drainage system to provide for distribution of the storage water throughout the reuse area, thus preventing the “low point” of the reuse area from having a shallow water table during times of the year when storage is required. The reuse area sizes are based upon the service area that provides drainwater to each site. Table C-4 gives a listing of the individual reuse service areas and sizes.

Table C-4
Reuse Service Area Sizes

Reuse Area	Gross Acres	Tiled Acres	Annual Drain Volume	Source Reductions		Reuse Inflow (AF/yr)	Reuse Size (acres)
				Groundwater Management (AF/yr)	Recycling (AF/yr)		
A	7,035	4,690	1,642	-136	-352	1,154	320
B	26,440	17,627	6,169	-512	-1,322	4,335	1,204
C	24,294	16,196	5,669	-470	-1,215	3,984	1,107
D	37,633	25,089	8,781	-728	-1,882	6,171	1,500
E	9,828	6,552	2,293	-190	-491	1,612	392
F	8,622	5,748	2,012	-167	-431	1,414	344
G	36,378	24,252	8,488	-704	-1,819	5,965	1,657
H	28,001	18,667	6,534	-542	-1,400	4,592	1,192
I	5,070	3,380	1,183	-98	-254	831	231
J	6,920	4,613	1,615	-134	-346	1,135	315
K	6,660	4,440	1,554	-129	-333	1,092	303
L	11,460	7,640	2,674	-222	-573	1,879	522
M	20,730	13,820	4,837	-401	-1,037	3,399	882
N	10,880	7,253	2,539	-211	-544	1,784	463
O	6,080	4,053	1,419	-118	-304	997	277
Z	81,000	54,000	38,080	-810	-4,700	29,460	8,200
All Areas	**327,031**	**218,020**	**95,489**	**-5,572**	**-17,003**	**69,804**	**18,909***

***Note**: The total reuse acreage is slightly larger than shown in Table 5-1 and will be refined following more detailed work on the individual service areas.

Reuse Area A is in the southernmost portion of Westlands. The collection area for former Reuse Area B is widespread in a north to south direction; so to minimize the collector system costs and minimize the pumping costs, former Reuse Area B has been split to now have a southern portion (designated Reuse Area A) and a northern portion (designated Reuse Area B). Both Reuse Areas A and B have been shifted slightly farther west than originally intended due to the subsurface drainage characteristics of the soils in this area. The drainage investigations for these reuse areas showed high clay contents and poor hydraulic conductivities in the subsoil along the Westlands eastern boundary in this area. Moving to the west provided for improved drainage characteristics.

Discharges from reuse areas would be combined and pumped to a treatment plant. The average annual discharge from the combination of areas is used as the supply rate for the treatment process. Tables C-5, C-6, and C-7 represent the combination of reuse sites and the destination as to which evaporation pond area the final water enters.

Table C-5
Westlands North Reuse Area with Source Controls

Area	Area (acres)	Annual Outflow (AF)	Average Outflow (AF/day)
I	231	249	0.68
J	315	340	0.93
K	303	328	0.9
L	522	564	1.54
M	882	1,020	2.79
N	463	535	1.47
O	277	299	0.82
Totals	**2,994**	**3,335**	**9.14**

Average Annual Discharge Rate: 4.61 cubic feet per second

Table C-6
Westlands Central Reuse Area with Source Controls

Area	Area (acres)	Annual Outflow (AF)	Average Outflow (AF/day)
D	1,500	1,851	5.07
E	392	483	1.32
F	344	424	1.16
G	1,710	1,847	5.06
H	1,192	1,377	3.77
Totals	**5,138**	**5,983**	**16.4**

Average Annual Discharge Rate: 8.26 cubic feet per second

Table C-7
Westlands South Reuse Area with Source Controls

Area	Area (acres)	Annual Outflow (AF)	Average Outflow (AF/day)
A	320	346	0.95
B	1,205	1,301	3.56
C	1,107	1,195	3.27
Totals	**2,631**	**2,842**	**7.79**

Average Annual Discharge Rate: 3.93 cubic feet per second

C9 NORTHERLY AREA: EXISTING DRAINAGE AND ADDITIONAL DRAINAGE

The Northerly Area contains a large amount of existing tiled land and some existing drainwater reuse. The addition of a small part (designated as Area Z) has been included in this estimate. The total amount of drainage production for the Northerly Area is a bit more complex in that some existing deep open drains contribute drainage flows that are not controlled as they would be using a pipeline collector system. The existing reuse area will remain a part of the final project along with some additional reuse acreage required to handle the entire drainage production. Estimates of drainage production for the Northerly Reuse Area have been made previously by URS and Summers Engineering. The estimated drainage rate to be used in this PFR has been discussed and agreed upon by the Technical Team.